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San Francisco Bay Triennial Bird Egg Monitoring Program for Contaminants – 2016 Data Summary

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Summary

As part of the *Regional Monitoring Program* (RMP) and the USGS's long-term *Wildlife Contaminants Program*, the USGS samples double-crested cormorant (*Phalacrocorax auritus*) and Forster's tern (*Sterna forsteri*) eggs throughout the San Francisco Bay Estuary approximately every three years to assess temporal trends in contaminant concentrations. This sampling has been carried out in 2006, 2009, and 2012. Although RMP sampling was scheduled to take place in 2015, it was delayed until 2016. This document summarizes egg collections for 2016, as well as mercury concentrations in Forster's tern eggs on an individual egg basis.

Egg Collection

Double-crested cormorants

Double-crested cormorant eggs were sampled between 4 April and 2 June 2016 from three locations: (1) Wheeler Island, (2) Richmond-San Rafael Bridge, and (3) Pond A9/A10 levee in the eastern Alviso salt pond complex of South San Francisco Bay (**Figure 1**). The Pond A9/A10 cormorant egg sampling location replaced the PG&E tower egg collections in the

Moffett area from 2009, but is the same site sampled for the RMP in 2006 and 2012. Twenty-four eggs were collected from 24 separate nests at each of the three locations (total of 72 eggs). This is 9 more eggs (3 more per site) than is typically collected for the RMP egg sampling design to account for potential egg breakage during whole-egg shipment. Egg mass, egg length, and egg width were measured for each cormorant egg (**Appendix 1**) and the cormorant eggs were shipped unopened to AXYS Analytical laboratories (Sidney BC, Canada) on 28 June 2016 for dissection, processing, contaminant analyses, and further reporting. AXYS confirmed receiving all 72 eggs. AXYS reported that 4 eggs (W2, W10, W15, and W22) were broken during shipment with some contents released into the surrounding whirl-pak. The remaining 68 eggs were all intact.

Forster's terns

Forster's tern eggs were sampled between 12 May and 22 June 2016 from four different colonies: (1) Pond AB1, (2) Pond AB2, and (3) New Chicago Marsh at the Don Edwards San Francisco Bay National Wildlife Refuge; and (4) Pond 2 at the Hayward Shoreline Regional Park (**Figure 2**). In 2016, Forster's terns did not nest at 2 sites sampled for RMP in previous years (Ponds A1 and A7), and at another previous RMP site (Pond A2W), Forster's terns did not nest at high enough nest densities to allow for egg collections.

Twenty-one Forster's tern eggs were collected from 21 separate nests at each of the four locations. Eggs were placed in egg cartons and stored on wet ice until transport back to the laboratory, where they were stored in a refrigerator until dissection. During egg dissection, refrigerated eggs were allowed to warm to room temperature before egg length and width were measured to the nearest 0.01 mm using digital calipers (Fowler) and total egg weight (including eggshell) was weighed to the nearest 0.01 g on a digital balance (Ohaus Adventurer Pro; Ohaus). Using clean, stainless steel instruments, we cut a hole approximately 15 mm in diameter in the wide end of each egg and removed the entire contents into a chemically cleaned and certified 60-mL jar (Thermo Scientific™ Wide-Mouth Short-Profile Amber Glass Jars, with PTFE-lined polypropylene lid). Egg content (without eggshell) was then weighed with a digital balance to the nearest 0.01 g, and egg contents were stored at –20ºC until processing and mercury determination. During processing, eggs were thawed at room temperature, and then the entire egg contents were dried at 50ºC for >48 h until completely dried. To determine moisture

content, we reweighed dried egg contents with a digital balance to the nearest 0.0001 g (Ohaus Adventurer Balance, model AR064; Ohaus). Dried egg contents were then homogenized to a powder using a spice grinder with stainless steel blades, followed by further grinding by hand in a mortar and pestle. Processed egg samples were stored in a desiccator until mercury determination.

Each tern egg was analyzed for total mercury (THg) concentrations at the USGS Dixon Field Station Environmental Mercury Laboratory on a Nippon MA-3000 Direct Mercury Analyzer (Nippon Instruments North America, College Station, Texas, USA) following Environmental Protection Agency Method 7473 (U.S. Environmental Protection Agency 2000), using an integrated sequence of drying, thermal decomposition, catalytic conversion, and then amalgamation, followed by atomic absorption spectroscopy. Prior research has demonstrated that an average of 96% of the mercury in eggs is in the methylmercury form, and that total mercury concentrations in eggs are very highly correlated with methylmercury concentrations in eggs (Ackerman et al. 2013).

Quality assurance measures included analysis of a certified reference material (either dogfish muscle tissue [DORM] or lobster hepatopancreas [TORT] certified by the National Research Council of Canada, Ottawa, Canada), system blank, method blank, continuing calibration verification, and duplicate with each set of approximately 10 samples, and two spiked duplicates with each batch of approximately 70 samples. For some egg duplicates, we used non-RMP eggs because we wanted to conserve as much RMP egg tissue as possible for subsequent contaminant analyses being conducted in other labs (see composite sampling methods below). Recoveries (mean ± standard deviation) were 98.7 ± 1.5% (N = 19) for certified reference materials, 102.5 ± 1.6% (N = 16) for continuing calibration verifications, and 99.5 ± 3.1% (N = 16) for matrix spikes. Relative percent difference averaged 1.7 ± 1.2% (N = 15) for duplicates and 2.5 ± 1.3% (N = 8) for matrix spike duplicates (**Appendix 3**).

After homogenizing the eggs, equal masses (dried) from each of seven randomly chosen eggs per colony were combined to make three separate composite samples of seven eggs each per colony (**Appendix 2**). Each composite sample was then re-homogenized and aliquots were put into jars provided by each lab. Egg samples were then shipped at room temperature to the California Department of Fish and Game Moss Landing Marine Lab (Moss Landing, CA) for selenium determination and to Applied Marine Sciences (Livermore, CA) for PBDE analyses on

November 16, 2016. Although egg samples were always stored in a desiccator up to the point of shipment, we recommend that subsequent labs re-dry the homogenized egg samples to remove any moisture before subsequent weighing and contaminant analysis.

Forster's Tern Egg Total Mercury Concentrations

Across all sites, the geometric mean (± standard error) total mercury concentration (μg/g fresh wet weight [fww]) in Forster's tern eggs was 1.07 ± 0.07 μg/g fww, and concentrations in individual eggs ranged from 0.25 μg/g to 4.36 μg/g fww (**Appendix 2**). Mercury concentrations in Forster's tern eggs varied among colonies (ANOVA: $F_{3,80} = 20.19$, $P < 0.001$) and were greatest in Ponds AB2, AB1, and New Chicago Marsh, and lowest in Pond 2 of Hayward Shoreline (**Figure 3**). Egg mercury concentrations varied greatly among individuals within the same colony (**Figure 3**), indicating that using composite samples would not adequately characterize risk of mercury to Forster's terns in San Francisco Bay.

We evaluated risk to Forster's tern breeding productivity by assessing individual egg mercury concentrations in relation to a benchmark value of 0.9 μg/g fww, which is associated with a 10% reduction in egg hatchability and an 18% reduction in nest survival (Ackerman and Eagles-Smith 2008, Eagles-Smith and Ackerman 2010) and this benchmark is close to common reproductive impairment benchmarks developed for bird blood and translated into equivalent egg concentrations using maternal transfer equations (Ackerman et al. 2016). Overall, 57% of eggs sampled (48 of 84) exceeded this 0.9 μg/g fww benchmark. Importantly, on a site-specific basis, 81% of eggs at the AB2 colony, 81% of eggs at the AB1 colony, and 52% of eggs at the New Chicago Marsh colony exceeded 0.9 μg/g fww, whereas only 14% of eggs from Pond 2 at Hayward Shoreline colony exceeded this value. Geometric mean mercury concentrations in Forster's tern eggs were greater in 2016 (1.07 ± 0.07 μg/g fww) compared to 2009 (0.97 ± 0.05 μg/g fww), but were very similar to 2012 (1.09 ± 0.04 μg/g fww). Egg mercury concentrations have increased each year at the Pond AB2 colony, but have declined at the Hayward Shoreline colony (**Figure 4**). The samples document egg mercury concentrations that continue to be above benchmarks for high risk of impaired reproduction to Forster's terns in San Francisco Bay.

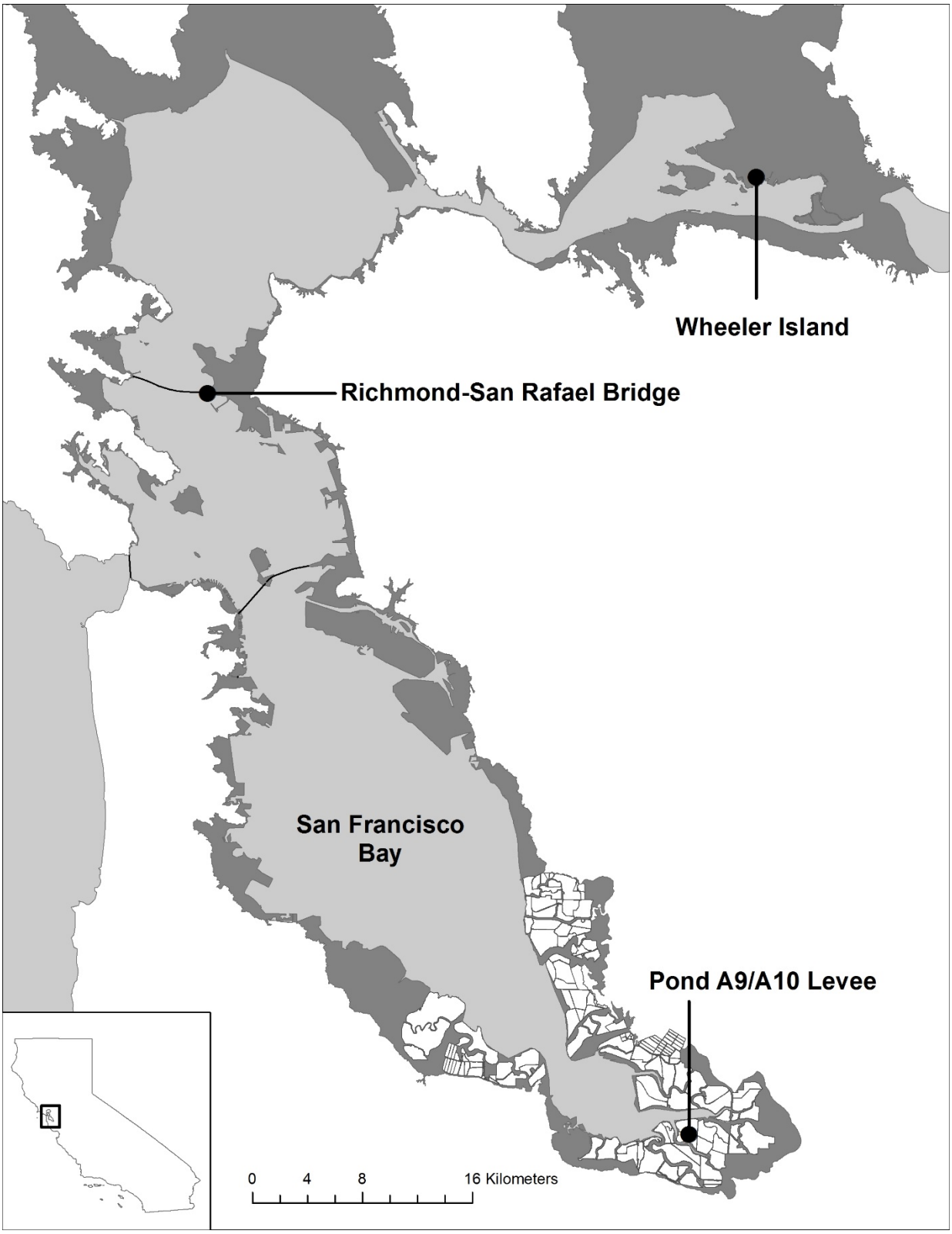

Figure 1. Double-crested cormorant colony locations that were sampled by USGS for the Regional Monitoring Program in 2016.

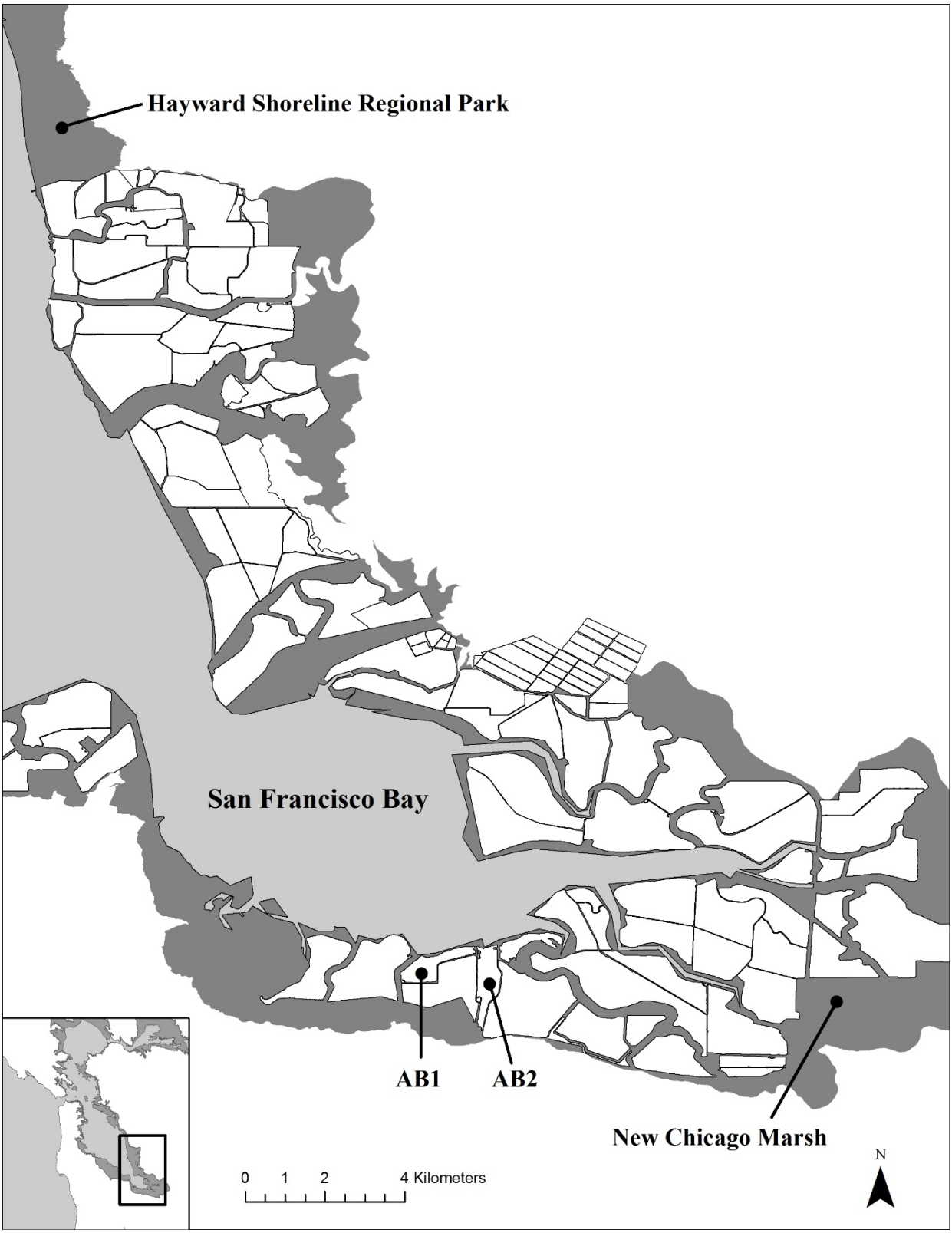

Figure 2. Forster's tern colony locations that were sampled by USGS for the Regional Monitoring Program in 2016.

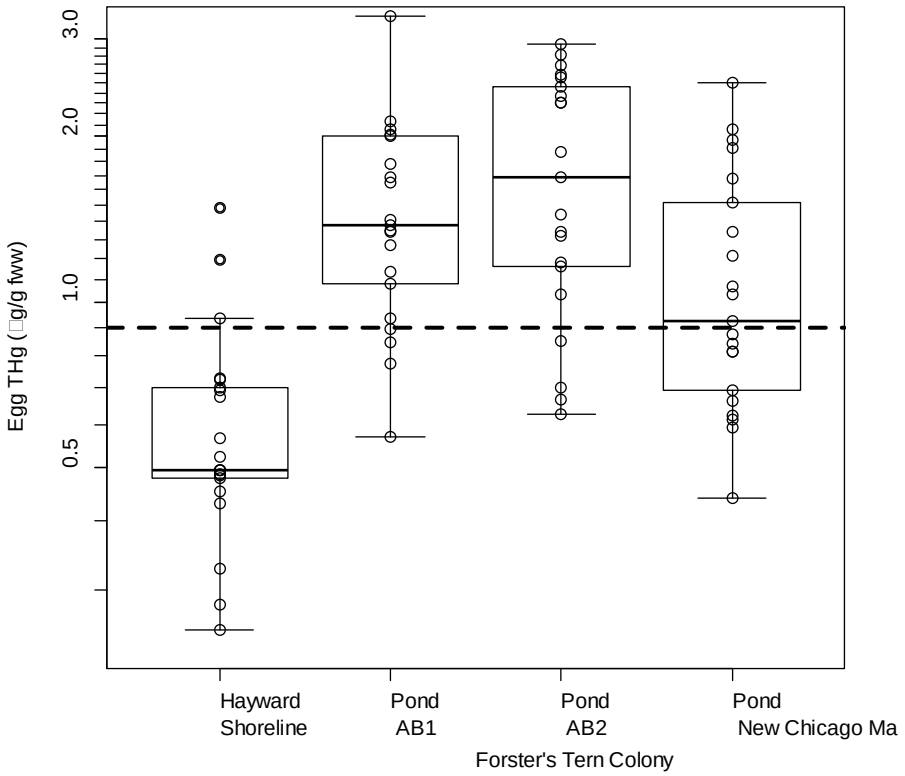

Figure 3. Total mercury (THg) concentrations (μg/g fresh wet weight [fww]) in Forster's tern eggs sampled from four colonies in San Francisco Bay during the 2016 breeding season. The stippled line indicates a benchmark value of 0.9 μg/g fww where tern reproduction may be impaired.

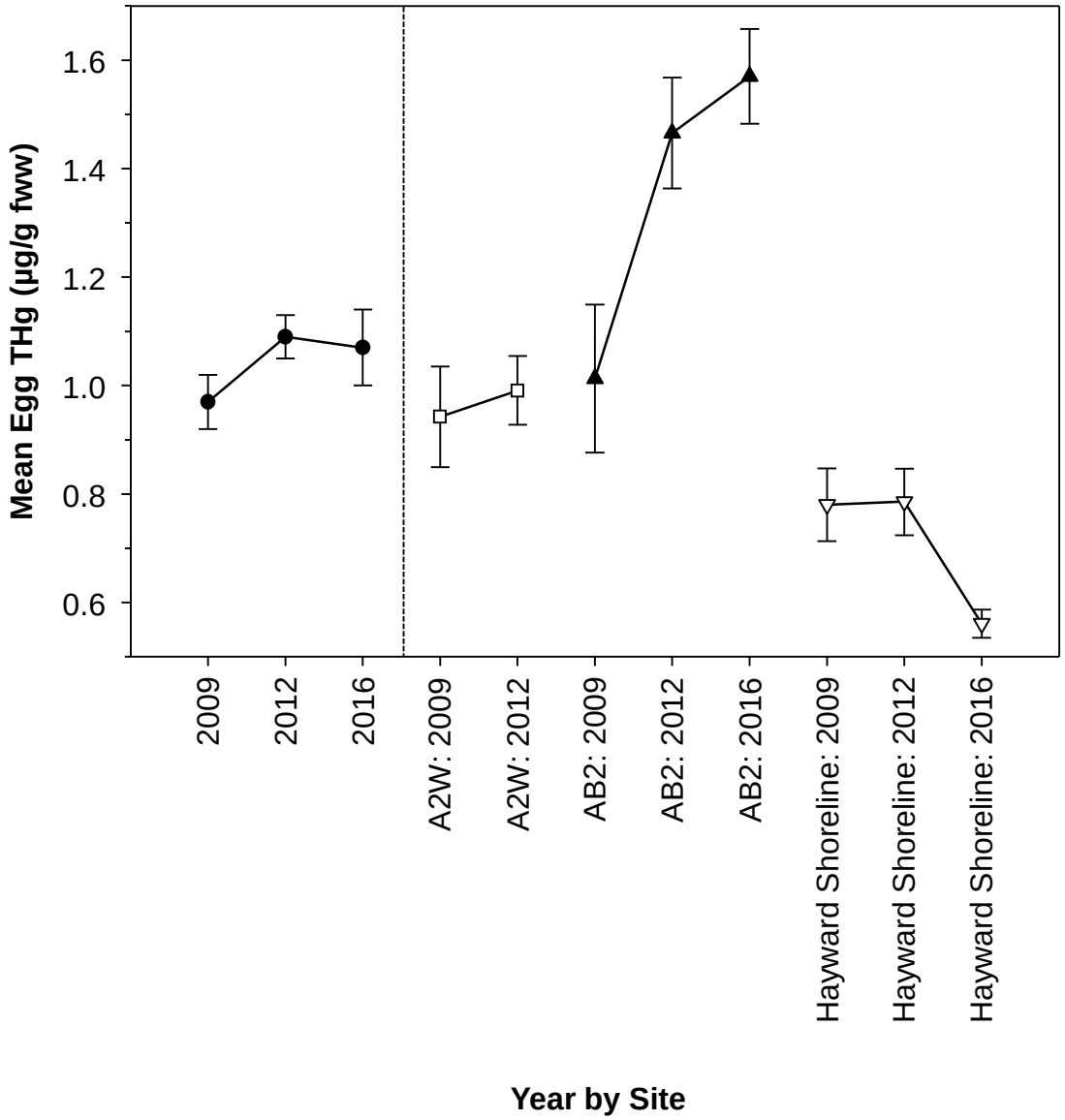

Figure 4. Mean ± standard error total mercury (THg) concentrations (µg/g fresh wet weight [fww]) in Forster's tern eggs in 2009 (Eagles-Smith and Ackerman 2009), 2012 (Ackerman et al. 2013), and 2016 (this report). In addition to the overall year comparison, we included comparisons between years for the three tern colony sites that were sampled in multiple years by USGS for the Regional Monitoring Program.

Literature Cited

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Appendix 1. Double-crested cormorant egg collection and measurement data for eggs collected by USGS from San Francisco Bay, California in 2016.

Sample ID	Field Collection ID	Species	Collection Date	Year	Colony	UTM-Easting (NAD83)	UTM-Northing (NAD83)	Egg measuring date	Whole Egg Mass (g)	Egg Length (mm)	Egg Width (mm)
W-1	W-1	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	45.85	61.71	37.55
W-2	W-2	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	49.64	65.70	39.11
W-3	W-3	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	38.83	55.86	36.47
W-4	W-4	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	46.72	58.62	39.26
W-5	W-5	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	50.69	62.40	39.24
W-6	W-6	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	46.16	61.57	38.34
W-7	W-7	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	50.15	59.94	40.00
W-8	W-8	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	43.77	59.99	37.54
W-9	W-9	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	49.63	62.71	39.41
W-10	W-10	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	43.38	61.96	37.91
W-11	W-11	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	45.55	55.69	40.21
W-12	W-12	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	43.47	59.29	37.27
W-13	W-13	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	39.96	55.00	37.15
W-14	W-14	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	50.43	63.75	39.51
W-15	W-15	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	46.01	62.05	38.66
W-16	W-16	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	48.42	62.31	39.53
W-17	W-17	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	49.04	64.01	37.90
W-18	W-18	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	43.90	60.30	37.51
W-19	W-19	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	48.71	62.60	39.33
W-20	W-20	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	51.14	61.17	40.26
W-21	W-21	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	42.59	62.46	37.75
W-22	W-22	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	47.27	61.21	39.55
W-23	W-23	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	48.29	63.26	38.52
W-24	W-24	Double-crested Cormorant	4/11/2016	2016	Wheeler Island	590750	4215217	6/21/2016	42.83	56.84	39.05
RB-1	RB-1	Double-crested Cormorant	5/3/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	42.50	60.70	36.48
RB-2	RB-2	Double-crested Cormorant	5/3/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	41.00	57.69	36.38
RB-3	RB-3	Double-crested Cormorant	5/3/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	45.00	58.85	38.16
RB-4	RB-4	Double-crested Cormorant	5/3/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	47.30	58.30	39.42
RB-5	RB-5	Double-crested Cormorant	5/3/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	43.59	59.52	36.98
RB-6	RB-6	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	45.13	58.44	39.42
RB-7	RB-7	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	43.48	57.89	38.55
RB-8	RB-8	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	41.46	60.14	37.55
RB-9	RB-9	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	47.99	62.61	37.96
RB-10	RB-10	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	40.98	58.99	37.54
RB-11	RB-11	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	53.70	63.70	40.06
RB-12	RB-12	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	46.54	60.29	37.85
RB-13	RB-13	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	44.02	57.40	38.09
RB-14	RB-14	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	49.77	58.31	39.57
RB-15	RB-15	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	42.06	60.90	36.96
RB-16	RB-16	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	43.33	57.83	37.72
RB-17	RB-17	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	52.54	64.07	39.99
RB-18	RB-18	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	48.23	63.85	39.45
RB-19	RB-19	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	46.39	59.80	38.14
RB-20	RB-20	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	45.61	59.77	38.30
RB-21	RB-21	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	41.00	61.99	35.16

Appendix 1. Continued.

Sample ID	Field Collection ID	Species	Collection Date	Year	Colony	UTM-Easting (NAD83)	UTM-Northing (NAD83)	Egg measuring date	Whole Egg Mass (g)	Egg Length (mm)	Egg Width (mm)
RB-22	RB-22	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	43.06	57.14	36.57
RB-23	RB-23	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	37.95	57.66	34.78
RB-24	RB-24	Double-crested Cormorant	6/2/2016	2016	Richmond Bridge	549605	4198701	6/21/2016	45.95	57.06	40.15
SB-1	16CE1	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588304	4145477	6/21/2016	46.26	61.52	38.46
SB-2	16CE2	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588302	4145479	6/21/2016	51.59	60.04	40.91
SB-3	16CE3	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588306	4145474	6/21/2016	47.29	61.38	38.21
SB-4	16CE4	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588708	4145304	6/21/2016	48.17	60.81	40.00
SB-5	16CE5	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588708	4145301	6/21/2016	53.87	63.36	42.00
SB-6	16CE6	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588306	4145476	6/21/2016	46.01	63.71	37.25
SB-7	16CE7	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588307	4145475	6/21/2016	44.94	61.68	39.18
SB-8	16CE8	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588305	4145475	6/21/2016	48.93	59.80	40.26
SB-9	16CE9	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588305	4145476	6/21/2016	45.36	61.93	37.63
SB-10	16CE10	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588307	4145475	6/21/2016	49.72	61.43	39.82
SB-11	16CE11	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588305	4145476	6/21/2016	44.42	57.76	37.71
SB-12	16CE12	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588306	4145476	6/21/2016	44.51	60.02	37.55
SB-13	16CE13	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588307	4145474	6/21/2016	44.48	59.47	38.26
SB-14	16CE14	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588301	4145480	6/21/2016	50.33	63.79	39.30
SB-15	16CE15	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588297	4145489	6/21/2016	52.29	62.17	41.09
SB-16	16CE16	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588300	4145483	6/21/2016	43.77	61.09	37.67
SB-17	16CE17	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588300	4145481	6/21/2016	47.27	63.41	38.75
SB-18	16CE18	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588301	4145480	6/21/2016	46.87	58.92	38.44
SB-19	16CE19	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588301	4145480	6/21/2016	45.13	58.18	38.73
SB-20	16CE20	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588299	4145477	6/21/2016	49.17	65.89	38.43
SB-21	16CE21	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588304	4145903	6/21/2016	52.53	60.58	40.83
SB-22	16CE22	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588688	4145308	6/21/2016	52.68	60.33	40.97
SB-23	16CE23	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588300	4145474	6/21/2016	47.24	58.21	39.36
SB-24	16CE24	Double-crested Cormorant	4/26/2016	2016	South Bay (A9/A10 levee)	588301	4145471	6/21/2016	47.59	58.09	39.35

Appendix 2. Forster's tern egg collection data and total mercury (THg) concentrations for eggs collected by USGS from San Francisco Bay, California in 2016.

Sample ID	Composite ID	Egg THg (µg/g dw)	Egg THg (µg/g fww)	Year	Colony	Egg Collection Date	Whole Egg Mass (g)	Egg Length (mm)	Egg Width (mm)	UTM-Easting (NAD83)	UTM-Northing (NAD83)	Egg Content Mass (g ww)	Egg Content Mass (g dw)	Percent Moisture
16FE10	AB1-1	6.69	1.68	2016	AB1	6/8/2016	20.68	43.31	30.76	582806	4144568	19.17	5.18	73.0
16FE12	AB1-1	8.34	2.02	2016	AB1	6/1/2016	19.33	41.10	30.80	588822	4144577	17.83	4.73	73.5
16FE6	AB1-1	3.16	0.77	2016	AB1	6/1/2016	18.28	41.38	29.95	582818	4144578	16.88	4.55	73.1
16FE69	AB1-1	3.60	0.89	2016	AB1	6/1/2016	20.83	44.31	30.41	582819	4144575	19.14	5.05	73.6
16FE81	AB1-1	13.81	3.31	2016	AB1	6/1/2016	18.52	42.49	29.82	582816	4144564	17.12	4.54	73.5
16FE89	AB1-1	4.40	1.14	2016	AB1	6/8/2016	19.96	44.14	30.39	582817	4144564	18.52	5.29	71.5
16FE93	AB1-1	3.75	0.93	2016	AB1	6/8/2016	20.18	42.53	31.26	582812	4144572	18.63	5.18	72.2
16FE13	AB1-2	2.54	0.57	2016	AB1	6/1/2016	20.60	43.61	30.93	582818	4144566	19.05	4.70	75.3
16FE168	AB1-2	3.02	0.85	2016	AB1	6/15/2016	19.93	44.83	30.12	582813	4144573	18.48	5.71	69.1
16FE46	AB1-2	5.60	1.35	2016	AB1	6/1/2016	21.85	45.84	30.96	582807	4144565	20.27	5.31	73.8
16FE48	AB1-2	8.70	2.13	2016	AB1	6/1/2016	20.35	44.31	30.29	582816	4144582	18.82	4.99	73.5
16FE55	AB1-2	8.20	2.07	2016	AB1	6/15/2016	19.14	42.97	30.23	582816	4144568	17.76	4.97	72.0
16FE88	AB1-2	5.52	1.27	2016	AB1	6/8/2016	17.90	44.45	28.83	582818	4144568	16.70	4.28	74.4
16FE9	AB1-2	5.77	1.41	2016	AB1	6/1/2016	18.42	42.07	30.11	582807	4144560	16.84	4.66	72.3
16FE15	AB1-3	7.34	1.64	2016	AB1	6/1/2016	18.03	43.89	29.51	582820	4144580	16.73	4.31	74.3
16FE16	AB1-3	4.66	1.08	2016	AB1	6/1/2016	19.25	44.33	29.37	582819	4144577	17.91	4.42	75.3
16FE41	AB1-3	6.19	1.38	2016	AB1	6/15/2016	19.18	41.69	30.65	582817	4144563	17.79	4.38	75.4
16FE43	AB1-3	7.84	1.78	2016	AB1	6/15/2016	18.52	45.09	28.71	582816	4144559	17.19	4.24	75.3
16FE70	AB1-3	6.01	1.34	2016	AB1	6/1/2016	21.77	45.82	31.06	582807	4144574	20.29	4.97	75.5
16FE84	AB1-3	8.55	2.01	2016	AB1	6/8/2016	16.57	41.20	28.96	582818	4144575	15.33	4.07	73.5
16FE90	AB1-3	19.05	4.36	2016	AB1	6/8/2016	20.33	44.72	30.43	582816	4144565	18.86	4.76	74.8
16FE19	AB2-1	12.40	2.81	2016	AB2	5/26/2016	17.99	41.38	29.84	584073	4143049	16.63	4.19	74.8
16FE241	AB2-1	9.40	2.30	2016	AB2	6/15/2016	18.53	42.73	29.47	584093	4143171	17.14	4.55	73.5
16FE42	AB2-1	10.91	2.56	2016	AB2	6/8/2016	17.12	38.78	30.52	584089	4143168	15.96	4.28	73.1
16FE68	AB2-1	5.80	1.44	2016	AB2	6/1/2016	19.11	42.12	30.43	584093	4143171	17.75	4.86	72.6
16FE79	AB2-1	5.39	1.34	2016	AB2	6/15/2016	21.38	44.05	31.07	584091	4143169	19.67	5.29	73.1

Appendix 2. Continued.

Sample ID	Composite ID	Egg THg (µg/g dw)	Egg THg (µg/g fww)	Year	Colony	Egg Collection Date	Whole Egg Mass (g)	Egg Length (mm)	Egg Width (mm)	UTM-Easting (NAD83)	UTM-Northing (NAD83)	Egg Content Mass (g ww)	Egg Content Mass (g dw)	Percent Moisture
16FE92	AB2-1	9.47	2.36	2016	AB2	6/15/2016	19.42	42.11	30.71	584085	4143172	18.03	4.98	72.4
16FE95	AB2-1	4.78	1.16	2016	AB2	6/8/2016	20.91	45.61	30.21	584098	4143162	19.26	5.05	73.8
16FE21	AB2-2	3.42	0.85	2016	AB2	5/26/2016	18.24	42.10	29.81	584089	4143167	16.89	4.68	72.3
16FE255	AB2-2	5.50	1.32	2016	AB2	6/15/2016	18.05	43.73	29.42	584095	4143169	16.63	4.55	72.6
16FE45	AB2-2	2.68	0.67	2016	AB2	6/15/2016	20.36	41.41	30.75	584097	4143182	18.94	4.89	74.2
16FE5	AB2-2	7.83	1.88	2016	AB2	5/26/2016	17.94	42.52	29.20	584075	4143048	16.55	4.35	73.7
16FE56	AB2-2	12.30	2.95	2016	AB2	6/8/2016	21.71	45.44	31.09	584095	4143171	20.24	5.30	73.8
16FE85	AB2-2	4.47	1.03	2016	AB2	6/8/2016	19.48	45.16	29.85	584095	4143168	18.01	4.64	74.3
16FE94	AB2-2	9.69	2.31	2016	AB2	6/8/2016	20.47	44.23	30.77	584095	4143165	18.97	4.99	73.7
16FE236	AB2-3	9.86	2.46	2016	AB2	6/22/2016	21.14	44.62	30.33	584090	4143162	19.70	5.16	73.8
16FE24	AB2-3	2.64	0.63	2016	AB2	5/26/2016	18.63	43.07	29.83	584090	4143165	17.11	4.54	73.5
16FE26	AB2-3	10.05	2.70	2016	AB2	6/1/2016	22.08	43.88	31.75	584096	4143168	20.65	5.98	71.0
16FE29	AB2-3	9.91	2.59	2016	AB2	6/8/2016	20.02	41.01	31.69	584090	4143165	18.42	5.38	70.8
16FE34	AB2-3	5.20	1.18	2016	AB2	6/8/2016	18.73	40.92	30.06	584090	4143165	17.45	4.24	75.7
16FE62	AB2-3	2.81	0.70	2016	AB2	6/1/2016	19.94	42.62	30.97	584089	4143168	18.43	5.11	72.3
16FE83	AB2-3	7.04	1.68	2016	AB2	6/8/2016	21.43	43.68	31.33	584095	4143175	19.81	5.13	74.1
16FE112	HS-1	1.06	0.25	2016	Hayward Shoreline	6/10/2016	19.06	43.94	30.14	575564	4164944	17.45	4.80	72.5
16FE114	HS-1	2.78	0.69	2016	Hayward Shoreline	6/10/2016	19.04	44.14	29.47	575556	4164956	17.65	4.78	72.9
16FE120	HS-1	1.79	0.43	2016	Hayward Shoreline	6/10/2016	22.26	44.25	30.67	575574	4164947	20.46	5.00	75.5
16FE172	HS-1	4.00	0.94	2016	Hayward Shoreline	6/10/2016	20.00	45.06	30.15	575534	4164952	18.39	4.79	74.0
16FE174	HS-1	2.31	0.52	2016	Hayward Shoreline	6/10/2016	20.13	45.25	29.67	575542	4164958	18.71	4.53	75.8
16FE180	HS-1	1.33	0.33	2016	Hayward Shoreline	6/10/2016	20.11	43.08	30.35	575558	4164947	18.66	4.92	73.6
16FE195	HS-1	1.20	0.28	2016	Hayward Shoreline	6/10/2016	19.55	44.18	29.50	575529	4164952	18.38	4.57	75.2
16FE115	HS-2	3.15	0.73	2016	Hayward Shoreline	6/10/2016	20.82	44.47	30.61	575571	4164945	19.29	4.80	75.1
16FE116	HS-2	2.39	0.49	2016	Hayward Shoreline	6/10/2016	19.27	41.68	29.96	575570	4164945	17.70	3.87	78.2
16FE121	HS-2	2.15	0.49	2016	Hayward Shoreline	6/10/2016	21.11	44.96	30.73	575570	4164951	19.71	4.83	75.5
16FE122	HS-2	3.10	0.70	2016	Hayward Shoreline	6/10/2016	20.82	45.82	30.79	575569	4164948	19.40	4.94	74.6

Appendix 2. Continued.

Sample ID	Composite ID	Egg THg (µg/g dw)	Egg THg (µg/g fww)	Year	Colony	Egg Collection Date	Whole Egg Mass (g)	Egg Length (mm)	Egg Width (mm)	UTM-Easting (NAD83)	UTM-Northing (NAD83)	Egg Content Mass (g ww)	Egg Content Mass (g dw)	Percent Moisture
16FE171	HS-2	1.97	0.48	2016	Hayward Shoreline	6/10/2016	18.67	42.03	29.79	575532	4164949	17.33	4.54	73.8
16FE179	HS-2	4.87	1.19	2016	Hayward Shoreline	6/10/2016	20.84	42.89	30.96	575563	4164952	19.37	5.05	73.9
16FE181	HS-2	6.16	1.48	2016	Hayward Shoreline	6/10/2016	21.42	43.77	30.66	575569	4164942	19.80	4.95	75.0
16FE113	HS-3	1.82	0.45	2016	Hayward Shoreline	6/10/2016	20.10	41.98	31.01	575562	4164950	18.79	5.09	72.9
16FE117	HS-3	2.26	0.50	2016	Hayward Shoreline	6/10/2016	19.51	44.74	29.70	575571	4164945	18.14	4.36	76.0
16FE118	HS-3	3.10	0.67	2016	Hayward Shoreline	6/10/2016	18.74	43.59	29.14	575564	4164943	17.52	4.06	76.8
16FE123	HS-3	3.03	0.73	2016	Hayward Shoreline	6/10/2016	20.18	43.25	30.58	575562	4164960	18.82	4.88	74.1
16FE124	HS-3	2.08	0.49	2016	Hayward Shoreline	6/10/2016	19.98	41.11	30.53	575554	4164951	18.52	4.56	75.3
16FE177	HS-3	2.36	0.57	2016	Hayward Shoreline	6/10/2016	19.36	44.72	29.15	575557	4164957	17.89	4.53	74.7
16FE178	HS-3	2.11	0.48	2016	Hayward Shoreline	6/10/2016	19.10	41.66	29.65	575563	4164951	17.60	4.19	76.2
16FE17	NCM-1	4.51	1.07	2016	New Chicago Marsh	5/24/2016	17.87	41.92	29.64	591379	4143958	16.48	4.37	73.5
16FE18	NCM-1	6.31	1.52	2016	New Chicago Marsh	5/24/2016	17.30	40.94	30.01	590973	4144100	16.01	4.46	72.2
16FE23	NCM-1	3.98	0.92	2016	New Chicago Marsh	5/20/2016	19.16	42.42	30.06	591425	4143830	17.85	4.48	74.9
16FE59	NCM-1	3.70	0.87	2016	New Chicago Marsh	5/20/2016	20.95	44.32	31.12	591451	4143863	19.35	5.07	73.8
16FE61	NCM-1	2.55	0.62	2016	New Chicago Marsh	5/27/2016	19.66	42.10	30.57	591446	4143862	18.18	4.81	73.6
16FE71	NCM-1	11.01	2.50	2016	New Chicago Marsh	5/20/2016	19.55	43.85	30.10	591373	4143953	18.07	4.52	75.0
16FE76	NCM-1	3.81	0.84	2016	New Chicago Marsh	5/20/2016	18.40	42.49	29.60	591433	4143841	16.88	4.09	75.8
16FE20	NCM-2	3.54	0.81	2016	New Chicago Marsh	5/20/2016	16.65	41.58	28.84	591369	4143949	15.41	3.98	74.2
16FE22	NCM-2	2.62	0.61	2016	New Chicago Marsh	5/20/2016	20.16	45.23	29.78	591426	4143830	18.76	4.71	74.9
16FE47	NCM-2	6.02	1.34	2016	New Chicago Marsh	5/20/2016	19.05	41.14	30.76	590886	4144147	17.57	4.34	75.3
16FE50	NCM-2	3.44	0.81	2016	New Chicago Marsh	5/20/2016	17.17	39.79	30.81	591341	4143975	15.84	4.49	71.7
16FE72	NCM-2	2.40	0.59	2016	New Chicago Marsh	5/20/2016	18.73	40.56	30.10	591380	4143956	17.43	4.57	73.8
16FE74	NCM-2	8.72	1.97	2016	New Chicago Marsh	5/24/2016	19.99	43.44	30.86	590977	4144104	18.51	4.69	74.7
16FE75	NCM-2	7.32	1.67	2016	New Chicago Marsh	5/20/2016	17.75	43.43	29.39	591425	4143830	16.31	4.29	73.7
16FE2	NCM-3	2.89	0.69	2016	New Chicago Marsh	5/12/2016	17.67	41.11	29.30	591353	4143915	16.38	4.25	74.1
16FE4	NCM-3	9.47	2.06	2016	New Chicago Marsh	5/24/2016	19.13	41.27	30.41	590978	4144104	17.71	4.16	76.5
16FE49	NCM-3	5.32	1.22	2016	New Chicago Marsh	5/20/2016	18.38	41.96	29.56	591329	4143984	16.94	4.19	75.2

Appendix 2. Continued.

Sample ID	Composite ID	Egg THg (µg/g dw)	Egg THg (µg/g fww)	Year	Colony	Egg Collection Date	Whole Egg Mass (g)	Egg Length (mm)	Egg Width (mm)	UTM-Easting (NAD83)	UTM-Northing (NAD83)	Egg Content Mass (g ww)	Egg Content Mass (g dw)	Percent Moisture
16FE51	NCM-3	1.94	0.44	2016	New Chicago Marsh	5/20/2016	18.57	41.84	29.51	590888	4144151	17.23	4.14	76.0
16FE57	NCM-3	8.36	1.90	2016	New Chicago Marsh	5/20/2016	17.34	40.98	29.61	590885	4144146	16.01	4.11	74.3
16FE58	NCM-3	3.01	0.66	2016	New Chicago Marsh	5/20/2016	19.27	46.33	29.24	591446	4143863	18.03	4.39	75.6
16FE73	NCM-3	4.56	1.04	2016	New Chicago Marsh	5/24/2016	18.68	41.70	29.78	590886	4144153	17.47	4.23	75.8

Appendix 3. Quality Assurance and Quality Control results for total mercury (THg) analyses of Forster's tern eggs collected by USGS from San Francisco Bay, California in 2016. Note that the percent recovery and relative percent difference values are based on non-rounded data, and therefore would differ slightly from the values obtained if they were calculated directly from the rounded data reported in these tables.

Certified Reference Materials (CRM)

Analysis Date	CRM	Certified Value THg (µg/g dw)	Measured THg (µg/g dw)	Percent Recovery
10/27/2016	DORM-4	0.41	0.40	97.4
10/27/2016	DORM-4	0.41	0.40	97.2
10/27/2016	DORM-4	0.41	0.40	98.7
10/28/2016	DORM-4	0.41	0.40	97.5
10/28/2016	DORM-4	0.41	0.39	95.7
10/28/2016	DORM-4	0.41	0.42	102.4
10/28/2016	DORM-4	0.41	0.40	97.5
10/28/2016	DORM-4	0.41	0.40	98.2
10/29/2016	DORM-4	0.41	0.40	97.6
10/29/2016	DORM-4	0.41	0.40	97.8
10/31/2016	DORM-4	0.41	0.40	98.0
10/31/2016	DORM-4	0.41	0.41	99.5
10/31/2016	DORM-4	0.41	0.41	98.8
10/27/2016	TORT-3	0.29	0.29	99.9
10/27/2016	TORT-3	0.29	0.29	99.7
10/28/2016	TORT-3	0.29	0.29	100.2
10/28/2016	TORT-3	0.29	0.29	100.7
10/31/2016	TORT-3	0.29	0.29	98.8
10/31/2016	TORT-3	0.29	0.29	99.2

Continuing Calibration Verifications (CCV)

Analysis Date	CCV	CCV Certified Value THg (µg/g ww)	Weight of CCV Sample (g)	Expected THg (ng)	Measured THg (ng)	Measured THg (µg/g dw)	Percent Recovery
10/27/2016	200 ng	1.0790	0.18324	197.72	201.33800	1.10	101.8
10/28/2016	200 ng	1.0790	0.18436	198.92	202.19700	1.10	101.6
10/28/2016	200 ng	1.0790	0.18424	198.79	201.93700	1.10	101.6
10/29/2016	200 ng	1.0790	0.18443	199.00	201.81400	1.09	101.4
10/31/2016	200 ng	1.0790	0.18600	200.69	204.84000	1.10	102.1
10/27/2016	50 ng	1.0790	0.04545	49.04	49.39300	1.09	100.7
10/28/2016	50 ng	1.0790	0.04569	49.30	49.80400	1.09	101.0
10/28/2016	50 ng	1.0790	0.04599	49.62	50.02300	1.09	100.8
10/29/2016	50 ng	1.0790	0.04592	49.55	50.11600	1.09	101.1
10/31/2016	50 ng	1.0790	0.04613	49.77	50.41300	1.09	101.3
10/27/2016	8.5 ng	0.1010	0.08029	8.11	8.37200	0.10	103.2
10/27/2016	8.5 ng	0.1010	0.08002	8.08	8.39500	0.10	103.9
10/28/2016	8.5 ng	0.1010	0.07994	8.07	8.49300	0.11	105.2
10/28/2016	8.5 ng	0.1010	0.08018	8.10	8.50400	0.11	105.0
10/31/2016	8.5 ng	0.1010	0.08023	8.10	8.42400	0.10	104.0
10/31/2016	8.5 ng	0.1010	0.08056	8.14	8.56400	0.11	105.3

Duplicates

Analysis Date	Sample ID	THg (µg/g dw) replicate 1	THg (µg/g dw) replicate 2	Relative Percent Difference
10/27/2016	16BE59	2.27	2.36	3.8
10/27/2016	16BE63	2.07	2.06	0.5
10/27/2016	16BE75	1.81	1.80	0.8
10/27/2016	16FE21	3.42	3.54	3.4
10/28/2016	16FE134	12.45	12.11	2.8
10/28/2016	16FE27	5.94	5.93	0.2
10/28/2016	16FE57	8.36	8.46	1.2
10/28/2016	16FE70	6.01	6.11	1.5
10/28/2016	16FE81	13.81	13.93	0.8
10/29/2016	16FE195	1.20	1.22	1.1
10/29/2016	16FE52	9.46	9.39	0.7
10/31/2016	16FE73	4.56	4.53	0.8
10/31/2016	16FE75	7.32	7.15	2.4
10/31/2016	16SNPL10	1.32	1.27	3.6
10/31/2016	16SNPL7	2.23	2.26	1.3

Matrix Spikes and Matrix Spike Duplicates

Analysis Date	Sample ID	Weight of Egg Sample (g)	Mean THg (µg/g dw) of Duplicate Samples Prior to Spiking	Expected THg (ng) from Egg Sample	THg (ng) Spike Amount	Total Expected THg (ng) of Egg Sample + Spike	Measured THg (ng) Egg Sample + Spike	Percent Recovered	Relative Percent Difference in Duplicate Spike Samples
10/27/2016	16BE63	0.02744	2.06	56.54	91.79	148.33	156.50	100.9	1.7
10/27/2016	16BE63	0.02716	2.06	55.97	91.56	147.53	154.03	99.3	
10/27/2016	16BE75	0.02655	1.81	47.95	92.14	140.09	152.19	104.8	2.0
10/27/2016	16BE75	0.02821	1.81	50.95	91.88	142.83	152.79	102.7	
10/28/2016	16FE134	0.02970	12.28	364.62	92.82	457.44	461.70	96.9	3.4
10/28/2016	16FE134	0.02915	12.28	357.87	91.88	449.75	450.74	93.7	
10/28/2016	16FE57	0.02934	8.41	246.68	92.26	338.94	345.38	99.1	1.7
10/28/2016	16FE57	0.02885	8.41	242.56	91.69	334.25	342.36	100.9	
10/28/2016	16FE70	0.02869	6.06	173.88	91.46	265.34	270.53	97.9	3.4
10/28/2016	16FE70	0.02945	6.06	178.49	91.76	270.25	278.83	101.4	
10/29/2016	16FE52	0.03014	9.43	284.11	92.04	376.14	380.93	97.5	4.0
10/29/2016	16FE52	0.03035	9.43	286.08	91.46	377.54	378.48	93.6	
10/31/2016	16FE75	0.02924	7.23	211.51	92.48	303.99	313.22	101.9	3.6
10/31/2016	16FE75	0.02906	7.23	210.21	92.38	302.59	308.22	98.3	
10/31/2016	16SNPL10	0.03157	1.29	40.85	92.53	133.38	142.24	101.5	0.3
10/31/2016	16SNPL10	0.03064	1.29	39.65	92.54	132.19	141.35	101.9	

System and Method Blanks

Analysis Date	Sample ID	THg (µg)
10/27/2016	Method blank	0.00002
10/27/2016	System blank	0.00002
10/27/2016	Method blank	0.00002
10/27/2016	System blank	0.00002
10/27/2016	System blank	0.00002
10/27/2016	Method blank	0.00002
10/27/2016	Method blank	0.00002
10/27/2016	System blank	0.00002
10/28/2016	System blank	0.00002
10/28/2016	Method blank	0.00003
10/28/2016	Method blank	0.00002
10/28/2016	Method blank	0.00003
10/28/2016	System blank	0.00003
10/28/2016	System blank	0.00003
10/28/2016	Method blank	0.00004
10/28/2016	System blank	0.00004
10/28/2016	Method blank	0.00003
10/28/2016	System blank	0.00003
10/28/2016	System blank	0.00003
10/28/2016	Method blank	0.00003
10/29/2016	Method blank	0.00004
10/29/2016	System blank	0.00004
10/29/2016	Method blank	0.00002
10/29/2016	System blank	0.00002
10/31/2016	System blank	0.00002
10/31/2016	System blank	0.00002
10/31/2016	Method blank	0.00001
10/31/2016	System blank	0.00003
10/31/2016	Method blank	0.00003
10/31/2016	Method blank	0.00001
10/31/2016	Method blank	0.00002
10/31/2016	System blank	0.00001